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Evaluation of production efficiencies at pasture of lactating suckler cows of diverse genetic merit and replacement strategy

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*Feed costs account for the largest proportion of direct cost within suckler beef production systems. By identifying the cow type with enhanced capability of converting grazed herbage to beef output across lactations, suckler cow systems would become more efficient and sustainable. The objective of this study was to estimate grass DM intake (**GDMI**) and production efficiency among lactating suckler cows of diverse genetic merit for the national Irish maternal index (Replacement Index) which includes cow efficiency components such as milk yield and feed intake. Data from 131 cows of diverse genetic merit within the Replacement Index, across two different replacement strategies (suckler or dairy sourced), were available over two grazing seasons. Milk yield, GDMI, cow live weight (BW) and body condition score (**BCS**) were recorded during early, mid and late-lactation, with subsequent measures of production efficiency extrapolated. Genetic merit had no significant effect on any variables investigated, with the exception of low genetic merit (LOW) cows being 22 kg heavier in BW than high genetic merit (HIGH) cows (P < 0.05). Beef cows were 55 kg heavier in BW (P < 0.001), had a 0.31 greater BCS (P < 0.05) and 0.30 Unité Fourragère Lait (UFL) greater energy requirement for maintenance compared to dairy sourced beef × dairy crossbred (**BDX**) cows (P < 0.001). The BDX had 0.8 kg greater GDMI, produced 1.8 kg more milk (P < 0.001), had a 0.8 UFL greater energy requirement for lactation and produced weanlings that were 17 kg heavier in BW than beef cows (P < 0.05). Subsequent efficiency variables of milk per 100 kg BW (P < 0.001), milk per kg GDMI (P < 0.001) and GDMI per 100 kg BW (P < 0.001) were more favourable for BDX. The correlations examined showed GDMI had moderate positive correlations (P < 0.001) with intake per 100 kg BW, net energy intake per kg milk yield, RFI and intake per 100 kg calf weaning weight but was weakly negatively correlated to milk yield per kg GDMI (P < 0.001). No difference was observed across genetic merit for beef cows for any of the traits investigated. Results from the current study showed that, while contrasting replacement strategies had an effect on GDMI and production efficiency, no main effect was observed on cows diverse in genetic merit for Replacement Index. Nonetheless, utilising genetic indexes in the suckler herd is an important resource for selecting breeding females for the national herd and phenotypic performance generated from this study can be included in future genetic evaluations to improve reliability of genetic values.*

Keywords: beef, genotype, grass, intake, milk yield

Implications

Results from this study highlight differences in production efficiency between beef cows from two contrasting replacement strategies. Differences between suckler cows of diverse genetic merit for maternal traits were also explored. The comparison in performance of cows of contrasting replacement strategies (i.e. beef *v*. beef × dairy cows) and diverse in genetic merit (i.e. high and low Replacement Index) within the current study demonstrates that Replacement Index had no influence on production efficiency within the suckler herd whereas replacement strategy can impact upon the efficiency of a suckler beef system.

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Introduction

Feed costs account for over 75% of direct costs (Finneran *et al.*, 2010) in beef suckler cow systems. Therefore, sustainable beef production is reliant on the efficient conversion of grazed herbage to beef output. In Ireland, suckler beef enterprises should comprise cows that are suited to 'low-input' pasture-based systems, exhibit high levels of reproductive performance and efficiently convert grazed pasture to milk production to generate a heavy calf at weaning. Suckler beef cows can consume 85% of total feed in grass-based calf-to-weanling systems (McGee, 2009), with two-thirds of this energy required for maintenance. Therefore, cow efficiency can be improved via selection of cows with superior conversion of energy intake to milk production, which is one potential way of increasing farm profit.

Due to the laborious nature of collecting milk yield data and estimates of grass DM intake (**GDMI**) at pasture for beef cows, production efficiency variables are difficult to ascertain, particularly in a pasture-based environment. Research to date has primarily used residual feed intake (**RFI**) to determine efficiency of feed use within the suckler herd (Crews, 2005; Lawrence *et al.*, 2013; Walker *et al.*, 2015). Independent of maintenance, growth or production levels, RFI is defined as the difference between actual feed intake and predicted feed intake (Koch *et al.*, 1963). Wright *et al.* (1994) demonstrated that genotypes with lower milk production levels resulted in greater biological efficiency levels due to lower energy requirements for milk production, whereas Lawrence *et al.* (2013) and Walker *et al.* (2015) reported more efficient beef genotypes, in terms of RFI, had similar levels of milk production with lower DM intake. This implies that cow genotype can have implications as to the efficiency of a suckler beef system.

A predominantly crossbred cow breed type exists in Ireland (McCabe *et al.*, 2018). The main replacement breeding strategies available to Irish farmers are beef cows either sourced within the beef herd (75%) or beef × dairy crossbred (**BDX**; 25%) generated from the dairy herd (Evans *et al.*, 2014). Typically, approximately 80% of these beef cows sourced within the beef herd were bred to a late-maturing bull (Department of Agriculture Food and the Marine, 2016). These contrasting cow types, which follow a breeding strategy utilised internationally, have shown differences in performance (McCabe *et al.*, 2018). McHugh *et al.* (2014) and McCabe *et al.* (2017) have previously outlined how utilising breeding values in the Replacement Index, the Irish national maternal genetic index, aims to improve maternal efficiency of the beef sector by selecting superior cows for maternal traits. The Replacement Index (McCabe *et al.*, 2019) is therefore a potential strategy available to producers to identify superior cows in terms of efficiency through the inclusion of traits such as maternal weaning weight (**WW**) (i.e. milk yield of the dam) and feed intake.

This study hypothesised that by identifying the suckler beef cow type with an enhanced capability of converting grazed herbage to beef output across lactations, the overall efficiency of beef suckler cow systems would be improved. Therefore, the objective of this study was to estimate GDMI and production efficiency among first and second lactation suckler cows of contrasting replacement strategy that were also genetically diverse for maternal traits under the Replacement Index.

Material and methods

This experiment was carried out at Teagasc, Grange Beef Research Centre, County Meath, Ireland. This study was conducted over two grazing seasons, from 2014 to 2015. Data collected from the 2014 grazing season on primiparous cows only have previously been reported by McCabe *et al.* (2017).

Beef heifers of diverse genetic merit for maternal traits were selected for the study at c. 8 months of age from beef suckler and dairy herds. Heifers were generated from either Aberdeen Angus (**AA**) or Limousin (**LM**) sires of high reliability (>70%) within the Irish national beef Replacement Index, with common sires used on the beef and dairy herd. A total of 193 records from 131 cows over two lactations were available: 70 high genetic merit (**HIGH**), 61 low genetic merit (**LOW**); 62 beef and 69 BDX cows. The Replacement Index value for HIGH and LOW was €119 (±€31) and €58 (±€32), respectively. A total of 23 sires were represented in HIGH and 19 sires represented in LOW. The mean predicted transmitting ability (**PTA**; the proportion of a particular trait that animal is expected to pass on to its progeny), across breed, for HIGH and LOW were −0.0016 and −0.0019 kg/day for feed intake, 10.66 and 8.11 kg for milk and 13.33 and 20.49 kg for live weight (BW), respectively. Mean calving date for year 1 was 21 March 2014 (±24 days) and year 2 was 22 March 2015 (±22 days).

All cows and their calves were turned out to pasture during March and April and grazed in four groups: two beef and two BDX. The groups were managed under a rotational grazing system as described by O'Donovan *et al.* (2002) on a predominantly perennial ryegrass (*Lolium perenne*) sward. Mineral supplementation (Royal Town and Country Stores, Meath, Ireland) was offered to the cows for long-term supply of trace elements, including calcined magnesite, and vitamins to aid in long-term mineral balance and also during periods of fast grass growth to assist in reducing the risk of hypomagnesaemia.

Sward measurements

Throughout the grazing periods (March to November), pre- and post-grazing sward heights were determined using a rising plate meter (Filip's Manual Plate Meter, Grasstec, Cork, Ireland). Forty pre- and post-grazing heights were taken across the paddocks with herbage mass determined and chemical analysis conducted as described by McCabe *et al.* (2019). During the intake measurement periods, herbage samples were collected on days 6 to 11 to represent herbage grazed. Samples were frozen at −20°C, bowl chopped, and a sub-sample of 100 g was freeze dried and then milled to facilitate analysis by the n-alkane technique (Mayes *et al.*, 1986).

Animal measurements

Cow BW was recorded every 3 weeks using a calibrated 'Titan Weigh Crate' (O'Donovan's Engineering, Cork, Ireland) combined with Tru-Test software (New Zealand). Live weight change (ΔBW) was calculated for each cow as forward differencing (i.e. the difference in BW between two consecutive weigh dates). Body condition score (**BCS**) was measured concurrently to BW by a single evaluator on a scale of 0 to 5 (Lowman *et al.*, 1976).

Milk yield measurements were taken twice in 2014, at 120 ± 23.5 and 156 ± 23.5 days in milk (**DIM**), and three times in 2015, at 52 ± 5.6, 131 ± 34.5 and 184 ± 23.1 DIM, using the weigh-suckle-weigh technique (McGee *et al.*, 2005b) as modified by McCabe *et al.* (2017). Briefly, milk yield estimates were determined twice daily at 0800 and 1500 h to give a 24 h average yield. This was conducted for 3 consecutive days on each cow during the measurement periods and an overall yield determined. Milk yield data on a day where a cow was not fully suckled out or a calf gained access to suckle the cow before the allotted measurement period were excluded from the analysis.

Calves were weaned using the gradual weaning technique (Enríquez *et al.*, 2011), where calves were allowed access to high quality pasture or 'creep grazing' 4 months prior to weaning and 'creep feeding' a minimum of 1 kg concentrate DM before removal of the cow from calf. Calf WW was recorded at 219 ± 24 days of age.

Feed efficiency

Estimates of individual GDMI were recorded for all cows during lactation to coincide with milk yield estimates at 126 ± 23.5 and 162 ± 23.5 DIM in 2014, and 58 ± 5.6, 137 ± 34.5 and 190 ± 23.1 DIM in 2015, using the n-alkane technique (Dillon, 1993). In brief, alkane dosing was conducted twice daily (0800 and 1500 h) for 12 consecutive days, beginning on the first day of the weigh-suckle-weigh technique. Faecal sampling was conducted twice daily (0600 and 1300 h) for 6 days commencing on day 7 of the alkane dosing. Based on the chemical analysis of the grass samples representative of what was consumed by the cows, the corresponding concentrations of net energy in the grass (Unité Fourragère Lait (**UFL**)/kg of DM) averaged 0.86 for 2014 and 1.04 for 2015, where 1 UFL is defined as the net energy content of 1 kg of standard barley for milk production (O'Mara, 2000).

Measures of gross efficiency subsequently calculated were milk yield per 100 kg BW and milk yield per kg GDMI, with intake capacity expressed as GDMI per 100 kg BW. As weanling output is a key indicator of a cow's maternal performance (Boggs *et al.*, 1980), cow milk yield per 100 kg calf WW and cow GDMI per 100 kg calf WW were also extrapolated. Energy balance (**EB**) was defined as the difference between energy intake and energy required for production, maintenance and BW change. Energetic efficiency of RFI was estimated by regressing energy intake on its assumed components:

$$Y = \beta 0 + \beta 1\ (\mathrm{BW}^{0.75}) + \beta 2\ (\Delta \mathrm{BW}) + \beta 3\ (\mathrm{Milk}) + \beta 4\ (\mathrm{BCS}) + \varepsilon$$

where Y = GDMI, $\beta 0$ was the intercept and $\beta 1$, $\beta 2$, $\beta 3$ and $\beta 4$ the partial regression coefficients of GDMI on $BW^{0.75}$ (metabolic live weight), ΔBW, milk yield and BCS, respectively, and ε was the residual term which represents RFI. The BCS nearest the week of intake measurement was included in the model based on the findings of Yan *et al.* (2006), who showed that BCS influenced the energy requirement for maintenance. Net energy requirement for maintenance at pasture was denoted as NE_M, and the requirement for milk production (NE_L) was assumed at 0.45 UFL/kg (O'Mara, 2000). The energy required to produce 1 kg of milk was expressed as NEI/MY; (NEI – NE_M)/MY represented the energy required to produce 1 kg of milk after accounting for maintenance; (NEI – ($NE_M + \Delta NE_M$))/MY indicates the energy required after adjusting for maintenance and BW change. Energetic efficiencies were further expressed as the energy required to produce 100 kg WW, with (NEI – NE_M)/100 kg WW accounting for maintenance and (NEI – ($NE_M + \Delta NE_M$))/100 kg WW adjusting for maintenance and BW change.

Statistical analysis

The effect of replacement strategy (beef or BDX), cow genetic index (HIGH or LOW) and their interaction on milk yield, BW, feed intake, RFI and all efficiency variables were undertaken using a linear mixed model in PROC HPMIXED (version 9.3; SAS Inst. Inc., Cary, NC, USA). Cow genetic merit (HIGH or LOW), replacement strategy (beef and BDX), the interaction between genetic merit and replacement strategy, sire breed (AA and LM) and parity were included as fixed effects in all models. Where BW, ΔBW, BCS and WW were the traits under investigation, weigh date was included as a fixed effect. For GDMI, milk yield, milk yield per 100 kg BW, milk yield per kg GDMI, GDMI per 100 kg BW, RFI, NE_M, NE_L and EB fixed effect of DIM were also included in the model. Calf sex and the calves sire PTA for carcass weight were also included as a fixed effect in the model for WW, milk yield per 100 kg WW and GDMI per 100 kg WW. Cow was included as a random effect which also accounted for the repeated records per cow.

Correlations between milk yield, BW, BCS, WW, intake capacity and efficiency variables across replacement strategy and cow genetic merit were investigated using partial Pearson correlations. The effect of breed, replacement strategy, cow genetic merit, parity and calving date were adjusted for the analysis using PROC CORR procedure of SAS.

Results

Sward measurements

Pre- and post-grazing sward surface heights and pre-grazing herbage yield throughout the grazing season of 2014 and 2015 are presented in Table 1. The chemical composition of the grass herbage available was of high quality (McEvoy *et al.*, 2010). The chemical composition of the herbage deemed to be selected by the animals during the individual GDMI measurement periods is presented in Table 2.

Table 1 *Pre- and post-grazing sward surface heights, pre-grazing herbage yield and chemical composition of grass offered to cows during the grazing seasons of 2014 and 2015*

Item	Mean	SD
Pre-grazing sward surface height (cm)	11.1	2.1
Post-grazing sward surface height (cm)	4.2	0.7
Pre-grazing herbage yield (kg DM/ha)	2336	868.5
Crude ash (g/kg DM)	104	15.9
CP(g/kg DM)	183	30.5
ADF (g/kg DM)	234	41.7
OMD (g/kg OM)	760	48.4
NDF (g/kg DM)	562	154

OMD = organic matter digestibility.

Table 2 *Chemical composition of herbage sampled to represent that selected by the cows during the intake periods of 2014 and 2015*

Item	Mean	SD
Crude ash (g/kg DM)	103	14.8
CP(g/kg DM)	186	35.0
ADF (g/kg DM)	238	59.6
OMD (g/kg OM)	755	56.3
NDF (g/kg DM)	535	141.8

OMD = organic matter digestibility.

Cow live weight, body condition score, milk yield and calf weaning weight. The effect of genetic merit and replacement strategy on BW and BCS is presented in Table 3. LOW cows were 22 kg heavier ($P < 0.05$) than HIGH; however, genetic merit had no significant effect on BCS. Beef cows were 55 kg heavier ($P < 0.001$) and had a 0.31 greater BCS ($P < 0.001$) than BDX. An interaction between cow genetic merit and replacement strategy was observed for ΔBW, with a 0.01 kg loss in BW recorded for BDX HIGH compared to a 0.23 kg loss in weight for BDX LOW cows ($P < 0.01$). Live weight change did not differ across genetic merit within beef cows. Beef cows had a 0.3 UFL greater NE_M requirement than BDX ($P < 0.001$), but no difference was observed between genetic merit. Genetic merit had no significant effect on milk yield, calf WW, NE_M or NE_L (Table 3). The BDX cows produced 1.8 kg more milk ($P < 0.001$) than beef, resulting in BDX having a greater lactation energy requirement (0.8 UFL; $P < 0.001$) than beef cows. Consequently, calf WW was 17 kg heavier for BDX than beef ($P < 0.05$).

Grass DM intake and efficiency parameters. Genetic merit had no significant effect on GDMI or efficiency parameters investigated (Table 4). An interaction between genetic merit and replacement strategy was observed for GDMI, NEI and GDMI per 100 kg BW. The BDX LOW had a 0.7 kg greater GDMI ($P < 0.05$) than BDX HIGH, 12.8 and 12.1 kg, respectively. No difference was observed across beef cows of contrasting genetic merit. The NEI values were 13.03 and 12.36 UFL for BDX LOW and HIGH, respectively (Table 5; $P < 0.05$). No significant difference was observed in the NEI values for beef LOW and HIGH at 11.85 and 12.09 UFL, respectively. The BDX LOW had a 0.10 kg greater GDMI per 100 kg BW ($P < 0.05$) compared to BDX HIGH, 2.35 and 2.25 kg, respectively. No significant difference was found for GDMI per 100 kg BW across genetic merit for beef cows.

The BDX produced 0.45 kg more milk per 100 kg BW ($P < 0.001$), 0.11 kg more milk per kg GDMI ($P < 0.001$) and 0.54 kg more milk per 100 kg WW ($P < 0.001$) than beef cows. No difference was found across genetic merit or replacement strategy for GDMI per 100 kg WW or EB.

An interaction was observed between genetic merit and replacement strategy for RFI (Table 5; $P < 0.01$). The BDX HIGH cows had a more favourable RFI value (−0.27) than BDX LOW (0.42; $P < 0.05$), whereas no difference was found across beef cows of contrasting genetic merit. Energetic efficiencies of production (Table 5) did not differ across genetic merit. Production efficiency expressed as NEI/MY was more favourable for BDX than beef cows ($P < 0.001$), whereas

Table 3 *Effect of cow genetic merit, replacement strategy and their interaction on BW, BCS, energy required for maintenance (NE_M), BW change (ΔBW), milk yield, corresponding energy intake (NE_L) and calf weaning weight*

	Genetic merit			Replacement strategy			*P*-value		
	High	Low	SE	BDX	Beef	SE	GM	RS	GM × RS
BW (kg)	577	599	7.7	561	616	7.7	*	***	NS
BCS (0 to 5)[1]	2.82	2.87	0.029	2.69	3.00	0.028	NS	***	NS
NE_M (UFL)	5.8	5.9	0.06	5.7	6.0	0.06	NS	***	NS
ΔBW (kg/day)	−0.06	−0.14	0.04	−0.12	−0.09	0.04	NS	NS	**
Milk yield (kg)	6.8	6.8	0.24	7.7	5.9	0.24	NS	***	NS
NE_L (UFL)	3.1	3.1	0.12	3.5	2.7	0.12	NS	***	NS
Calf weaning weight (kg)	278	277	5.4	286	269	5.2	NS	*	NS

BCS = body condition score; NE_M = net energy for maintenance; NE_L = net energy for lactation; SE = weighted standard error of the mean; BDX = beef × dairy cows; NS = non-significant.
[1]BCS range: 0 = emaciated, 5 = extremely fat.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 4 *Effect of cow genetic merit, replacement strategy and their interaction on GDMI and gross efficiency measures*

	Genetic merit			Replacement strategy			*P*-value		
	High	Low	SE	BDX	Beef	SE	GM	RS	GM × RS
GDMI(kg/day)	11.90	12.11	0.291	12.40	11.60	0.286	NS	***	*
GDMI/100 kg BW (kg)	2.13	2.13	0.036	2.30	1.96	0.035	NS	***	*
Milk yield/100 kg BW (kg)	1.22	1.21	0.053	1.44	0.99	0.052	NS	***	NS
Milk yield/GDMI (kg)	0.58	0.57	0.023	0.63	0.52	0.022	NS	***	NS
Milk yield/100 kg WW	2.54	2.55	0.084	2.81	2.27	0.081	NS	***	NS
GDMI/100 kg WW	4.50	4.56	0.108	4.54	4.52	0.104	NS	NS	NS

GDMI = grass DM intake; SE = weighted standard error of the mean; BDX = beef × dairy cows; NS = non-significant; WW = weaning weight.
*$P < 0.05$; ***$P < 0.001$.

Table 5 *Effect of cow genetic merit, replacement strategy and their interaction on NEI, energy balance, RFI and NEI per unit of production*

	Genetic merit			Replacement strategy			*P*-value		
	High	Low	SE	BDX	Beef	SE	GM	RS	GM × RS
NEI(UFL)	12.22	12.44	0.235	12.69	11.97	0.222	NS	**	*
Energy balance (UFL)	3.27	3.39	0.219	3.50	3.16	0.227	NS	NS	NS
RFI (UFL)	−0.37	−0.19	0.201	−0.07	−0.64	0.201	NS	***	**
NEI/MY (UFL/kg)	1.97	2.05	0.109	1.82	2.20	0.103	NS	***	NS
$(NEI - NE_M)/MY$ (UFL/kg)	1.03	1.07	0.057	1.01	1.09	0.054	NS	NS	NS
$(NEI - (NE_M + \Delta NE_M)/MY)$ (UFL/kg)	1.02	1.07	0.055	1.02	1.07	0.052	NS	NS	*
$(NEI - NE_M)$/100 kg WW (UFL/kg)	1.87	1.90	0.069	2.06	1.71	0.066	NS	***	**
$(NEI - (NE_M + \Delta NE_M)$/100 kg WW) (UFL/kg)	1.87	2.01	0.099	2.14	1.74	0.095	NS	***	**
$NE_L/(NEI - NE_M)$	0.57	0.57	0.032	0.58	0.57	0.031	NS	NS	NS

NEI = net energy intake; RFI = residual feed intake; SE = weighted standard error of the mean; BDX = beef × dairy cows; NS = non-significant; MY = milk yield; NE_M = net energy for maintenance; NE_L = net energy for lactation; WW = weaning weight.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

adjustment for maintenance and subsequently energy required for BW change showed no effect across replacement strategy. An interaction was observed between genetic merit and replacement strategy for $(NEI - (NE_M + \Delta NE_M))/MY$, where BDX LOW had a greater energy requirement of 1.1 UFL compared to 0.94 UFL for HIGH ($P < 0.05$) but no difference was observed across genetic merit for beef cows. When energetic efficiency was expressed per 100 kg WW, a similar interaction was observed between genetic merit and replacement strategy. The BDX LOW had an energy requirement for $(NEI - NE_M)$/100 kg WW of 2.17 compared to 1.94 UFL for HIGH and subsequently an energy requirement of 2.40 compared to 1.89 for $(NEI - (NE_M + \Delta NE_M))$/100 kg WW, respectively ($P < 0.01$). No difference was observed across genetic merit for beef cows for any of the traits investigated.

Correlations

Correlations between the various animal performance and efficiency variables across the two different replacement strategies and contrasting genetic merit are presented in Table 6. Milk yield had a strong positive correlation ($P < 0.001$) with milk yield per 100 kg BW, milk yield per kg GDMI and milk yield per 100 kg WW but had a weak negative correlation with RFI ($P < 0.01$) and a strong negative correlation with NEI per kg milk yield. Live weight had moderate positive correlations with BCS and GDMI ($P < 0.001$) but had weak negative correlations with milk yield per 100 kg BW, GDMI per 100 kg BW ($P < 0.001$) and milk yield per kg GDMI ($P < 0.05$). Grass DMI had moderate positive correlations ($P < 0.001$) with GDMI per 100 kg BW, NEI per kg milk yield, RFI and intake per 100 kg WW but was weakly negatively correlated with milk yield per 100 kg GDMI ($P < 0.001$). Calf WW had no correlation with any of the performance or efficiency variables examined ($P > 0.01$) with the exception of a moderate negative correlation with milk yield per 100 kg WW, NEI per 100 kg WW and GDMI per 100 kg WW ($P < 0.001$).

Discussion

Traditionally, key performance indicators within a beef system were kilograms of beef output on a live weight or carcass weight basis (Taylor *et al.*, 2018). While accounting for costs of production are also necessary in determining overall system profitability, efficiency within a system is the most critical factor that should be considered. To date, however, published literature examining production efficiency within the

Table 6 *Correlations (P-values in parentheses) between various animal performance and efficiency variables across beef and beef × dairy high and low genetic merit cows*

Item	BW	BCS	GDMI	MY/100 kg BW	GDMI/100 kg BW	MY/GDMI	RFI	NEI/MY	WW	MY/100 kg WW	GDMI/100 kg WW	(NEI − NE_M)/MY	(NEI − NE_M)/100 kg WW
MY	0.05 (NS)	−0.04 (NS)	0.14 (NS)	0.93***	0.11 (NS)	0.89***	−0.21**	−0.71***	0.12 (NS)	0.72***	−0.06 (NS)	−0.59***	−0.01 (NS)
BW		0.51***	0.52***	−0.30***	−0.29***	−0.16*	0.12 (NS)	0.25***	0.07 (NS)	−0.01 (NS)	0.23**	0.21**	0.18*
BCS			0.10 (NS)	−0.21**	−0.32***	−0.06 (NS)	0.01 (NS)	0.20**	0.01 (NS)	−0.06 (NS)	0.04 (NS)	0.15*	−0.02 (NS)
GDMI(kg/day)				−0.05 (NS)	0.66***	−0.28***	0.49***	0.32***	0.11 (NS)	−0.002 (NS)	0.47***	0.50***	0.67***
MY/100 kg BW					0.20**	0.91***	−0.28***	−0.69***	0.09 (NS)	0.69***	−0.14 (NS)	−0.58***	−0.06 (NS)
GDMI/100 kg BW						−0.18*	0.43***	0.16*	0.09 (NS)	−0.02 (NS)	0.30***	0.39***	0.58***
MY/GDMI							−0.42***	−0.76***	0.07 (NS)	0.67***	−0.25***	−0.73***	−0.28***
RFI								0.27***	−0.11 (NS)	−0.14 (NS)	0.31***	0.35***	0.36***
NEI/MY									0.02 (NS)	−0.57***	0.19*	0.95***	0.31***
WW										−0.5***	−0.77***	0.08 (NS)	−0.45***
MY/100 kg WW											0.43***	−0.51***	0.26***
GDMI/100 kg WW												0.24***	0.87***
(NEI − NE_M)/MY													0.44***

BW = live weight; BCS = body condition score; GDMI = grass DM intake; MY = milk yield; RFI = residual feed intake; NEI = net energy intake; NE_M = net energy for maintenance; NS = non-significant; WW = weaning weight.
$^*P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$

suckler herd is lacking, particularly within the context of a pasture-based system. Since grass is the main feed source (grazed or conserved) for suckler beef systems in Europe (Lawrence *et al.*, 2012), a comprehensive investigation of GDMI and subsequent production efficiency measures by suckler cows is essential to help maximise the efficiency of these intensive pasture-based systems of production. Therefore, the objective of this study was to examine production efficiency within the suckler herd, focusing on the implication of replacement strategy, while also quantifying the effect of genetic merit for the Replacement Index on the production efficiency of lactating cows at pasture.

Cow live weight and body condition score

Expected phenotypic differences between BDX and beef were as anticipated in the current study. Consistent with previous findings (Montano-Bermudez *et al.*, 1990; McGee *et al.*, 2005a), beef cows in the present study were heavier and had a greater BCS and consequently had a greater maintenance requirement than BDX.

An animal's PTA indicates the amount of a particular trait that animal is expected to pass on to its progeny, equating to half of its own breeding value (Mrode and Thompson, 2005). The divergence between HIGH and LOW cows was outlined by McCabe *et al.* (2019) in the expected PTA difference between genetic merit groups. An expected difference of 7.16 (SD = 12.49) kg greater BW for the LOW group was in agreement with the trend that the phenotypic results observed for cows of diverse genetic merit.

Cow milk yield and calf weaning weight

The superior milk yield of BDX to the beef cow is widely acknowledged (Wright *et al.*, 1994; McGee *et al.*, 2005b; Fraga *et al.*, 2016). Results of the current study supported these findings with BDX having a 23% greater milk yield compared to beef cows. However, the values reported in the current study for both BDX and beef are lower than previous findings (Jenkins and Ferrell, 2002; McGee *et al.*, 2005b). This may be attributed to Jenkins and Ferrell (2002) examining feeds differing in quantity of dietary energy or both studies utilising more mature cows. Although the milk yield observed for beef cows in the current study is consistent with that reported for Limousin cows by Murphy *et al.* (2008), BDX cows in the current study yielded 21% less milk than the Limousin x Friesian reported by Murphy *et al.* (2008) during mid-lactation. The lower milk yield of BDX in the current study may be attributed to the inability of the calf to consume the available milk yield, particularly during peak lactation (52 ± 5.6 DIM) when the calf is younger and lighter than subsequent measurement periods. The subsequent energy requirements for lactation reported in the current study reflect the yields that were observed, with BDX having a greater energy demand to counter the increased production levels (Montano-Bermudez *et al.*, 1990).

Calf pre-weaning performance and ultimately WW are widely accepted to be driven by cow milk yield (McGee *et al.*, 2005b; Walmsley *et al.*, 2016). As demonstrated using the Irish national database by McCabe *et al.* (2018), results of the current study also showed that progeny from BDX cows was heavier at weaning than those from beef cows.

The HIGH cows were expected to have an approximate 2.55 (SD = 5.99) kg increase in milk production per unit increase in PTA compared to LOW. This anticipated difference however was not realised, with similar milk yield observed among cows diverse in genetic merit for the Replacement Index. The lack of differences in milk yield between the two groups directly influenced the lack of differences observed between energy requirements or subsequent calf performance.

Grass DM intake and efficiency parameters

Studies quantifying variation in GDMI between BDX and beef cows in an intensive pasture-based system are limited. However, an increase in GDMI for BDX (0.80 kg) is consistent with the findings of Murphy *et al.* (2008) who reported a 1 kg increase in GDMI as the proportion of dairy ancestry increased when comparing a Limousin to a Limousin x Holstein-Friesian, which was attributed to lactation energy demands. Previous studies showed that the influence of dairy genetics, that is, greater potential to produce milk, within the BDX replacement strategy may directly impact GDMI due to the higher intake capacity of dairy cows (Coleman *et al.*, 2010; Walker *et al.*, 2015). Lawrence *et al.* (2013) reported that approximately 2 kg per day less GDMI was consumed by purebred suckler beef cows of equivalent parity to the cows in the current study. However, GDMI reported in the first year of the study by Marshall *et al.* (1998) was consistent with results presented in the current study.

Archer *et al.* (1999) reported that cow/calf efficiency encompasses total feed intake during the production period compared to kilograms of calf weight weaned and is the best predictor of 'real' production efficiency within the breeding herd both biologically and economically. However, GDMI per 100 kg WW extrapolated in the current study showed no differences among the two replacement strategies investigated. Alternative measures of gross efficiency relating GDMI to production and BW were more favourable for BDX due to their ability to produce greater milk yield per kg GDMI and BW than beef cows. This method of expressing efficiency however reflects the issues highlighted by Berry *et al.* (2009) with ratio measures as BDX cows, due to their lower maintenance requirement and lighter BW, inevitably appear more efficient. Therefore, while results have shown that beef cows had lower GDMI, lower milk yield and subsequently lower calf WW, when RFI is considered which eliminates the variation between groups created by different levels of production, beef cows in the current study proved more efficient (see Table 5). Lawrence *et al.* (2013) reported the high RFI exhibited by BDX may be a consequence of the necessity to consume greater levels of feed to meet increased energy requirements for milk synthesis. Additionally, selection within the dairy herd for increased intake capacity to complement an intensive grazing environment (Prendiville *et al.*, 2009) in contrast to selection within the beef herd for reduced intakes substantiates this.

For every increase in PTA for feed intake, HIGH cows were expected to consume 0.0003 kg less per day compared to the LOW group. This counters what was observed in the current study. While the biological trend is in the right direction and HIGH cows consumed less GDMI than LOW, genetic merit had no statistical influence on GDMI or any of the efficiency variables investigated. This further corroborates issues previously highlighted with ratio measures of efficiency as the absolute production measures of milk yield and GDMI were similar between genotypes. However, for RFI the interaction observed within BDX cows was in line with the trend expected in PTA's where HIGH BDX cows proved more efficient in that less feed was required to produce similar milk yields.

Correlations

Practically, information relating to production efficiency within the beef suckler herd is difficult and costly to acquire, that is, milk yields and intakes at pasture using the n-alkane technique. Therefore, variables that can be correlated with production efficiency and that are more easily measured may be beneficial at farm level to select for improved cow efficiency. Fiss and Wilton (1992) showed that increased cow BW was associated with increased BCS, milk yield and feed intake. The current study also reported positive correlations for BW with BCS and GDMI. Where this may lead to the assumption that increased BW will therefore be less efficient, the positive correlation between BW and GDMI per 100 kg WW illustrates that in terms of cow/calf efficiency the opposite holds true. Furthermore, as lactation progresses cow milk yield diminishes (Gaskins and Anderson, 1980) while calf weight increases, resulting in the negative correlation observed between WW and milk yield expressed per 100 kg WW. Edwards *et al.* (2017) reported that milk yield may actually only be a determinant of calf BW up to day 60, accounting for 40% of the variation in WW, when forage intake by the calf itself increases. This signifies that while selection for milk yield is important within the suckler herd, it should not be the sole consideration for improving system performance.

Conclusion

The use of contrasting replacement strategies showed differences in production efficiency that may be utilised in identifying suitable beef cows for pasture-based systems. While BDX appears more favourable in terms of production outputs of milk yield, calf WW and subsequent efficiency variables extrapolated, this was offset by a requirement for greater herbage intakes. Consequently, this would need to be considered in an economic capacity to comprehensively evaluate overall farm profitability between the alternating strategies.

It was anticipated that selecting females based on the overall Replacement Index would result favourably in phenotypic performance. Results from the current study showed however that genetic selection for maternal traits had no effect on production efficiency of cows diverse in genetic merit for Replacement Index. Nonetheless utilising genetic indexes in the suckler herd is an important resource and phenotypic performance generated from the current study can be included in future genetic evaluations to improve the reliability of genetic values.

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Declaration of interest

The authors wish to confirm that there are no known conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.

Ethics statement

Animal procedures undertaken in this experiment were approved by the Teagasc Animal Ethics Committee and licensed by the Health Products Regulatory Authority in accordance with the protection of animals used for scientific purposes (Directive 2010/63/EU).

Software and data repository resources

None of the data were deposited in an official repository.

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